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Incentives and barriers for participation in community-based environmental monitoring and information systems: A critical analysis and integration of the literature

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ABSTRACT

The reliance of environmental management on comprehensive, high quality, timely and (ideally) affordable data and information has given rise to the need for 'shared environmental information systems' (SEIS). Community-based monitoring and information systems or 'citizen observatories' are a form of SEIS whereby citizens are involved in new roles such as data collection for environmental monitoring, data and knowledge sharing for joint decision- making, and cooperative planning. Despite the technological advances and the notional potential, many efforts to implement community-based monitoring systems (CBM) are facing difficulties with engaging the core stakeholder. The success of CBMs relies on the active participation and commitment of *all* involved stakeholders: citizen, decision and policy makers, and (private) data aggregators and scientists. This requires in-depth understanding of their motivations, incentives and barriers for participating.

This paper draws on the Theory of Planned Behaviour as an organising theoretical framework and reviews the (dispersed) empirical insights from the literature in order to generate an integrated overview of the incentives and barriers of the aforementioned stakeholders to participate in CBMs. The insights from the literature allow us to take stock of the state of research into motivations for CBM participation, to identify complementary and conflicting incentives for the respective actors, and to indicate gaps to be addressed in future research.

1. Introduction

The reliance of environmental management on comprehensive, high quality, timely and (ideally) affordable data and information has given rise to the need for 'shared environmental information systems' (SEIS), consisting of the harmonization and management of environmental data and information across governance levels and regions via a set of guiding principles and the implementation of three pillars (content, infrastructure and governance). Intended for collecting, exchanging and making accessible data and information about the environment as evidence in policy making processes for obligatory monitoring and reporting, and for emergency and disaster management by national or local authorities, the ultimate purpose of SEIS is to improve the quality of the environment. Since the initiation of this policy instrument (European Commission, 2008), progress has been made; in parallel with related regulatory and technical initiatives, SEIS capacity has been built via various efforts but challenges also persist (UNECE, 2016; Aggestam, 2019). Priority areas were set by the SEIS Implementation Outlook in order to address shortcomings in its implementation. This stresses that the way data is provided and accessed has changed drastically and, hence, emphasizes not only public access to environmental information but also the participation of the public in the collection and dissemination of environmental data and information (European Commission, 2013), as is the case with Citizen Science more generally. Indeed, innovative information and communication technologies (ICTs) are accelerating Citizen Science, presenting additional means for environmental monitoring, data and knowledge sharing for joint decision-making, and cooperative planning that can support informed and demand-driven policy responses (Wehn et al., 2015; Pick, 2007; Hrebicek et al., 2008; Conrad and Daoust, 2008). Easy-to-use sensors, the Global Positioning System and camera-equipped smart phones to collect data coupled with electronic communication, online platforms and social media provide channels for data and knowledge exchange and the means for new forms of citizen participation in decision making processes (Wehn and Evers, 2015) as well as monitoring progress towards achieving distinct targets of the Sustainable Development Goals (Fritz et al., 2019). Involving citizens in new roles such as data collection, these initiatives are called community-based monitoring and

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information systems (European Commission, 2013; Whitelaw et al., 2003). They are defined as "*a process where concerned citizens, government agencies, industry, academia, community groups, and local institutions collaborate to monitor, track and respond to issues of common community [environmental] concern*" (Whitelaw et al., 2003, p.410).

Recent examples include the 'Curious Noses' project in the Belgian province Flanders which mapped air quality using citizen-based monitoring, showing the spatial variations of air quality which explain how traffic and spatial planning influence air quality (De Straand, 2019). Air quality measurements were collected by 20,000 participants in 19,161 locations over a period of one month in spring 2018. This CBM generated data that was not available before and created support for the debate on air quality in Flanders. Other examples include CBMs around the globe for monitoring water quality and/or quantity that help address water use conflicts and to identify sources of pollution (Buytaert et al., 2014; Jollymore et al., 2017; Kinchy, 2017; Wehn et al., 2018).

As a form of SEIS, CBMs rely on citizens as a key actor and as such they apply the notion of data and information generation, exchange and use at the local level, with the potential to trigger a paradigm shift in environmental management. Despite the technological advances and the notional potential, many CBM efforts are facing problems with their implementation since the success of these systems relies on the active participation and commitment of *all* involved stakeholders: citizens, scientists and other data aggregators, decision and policy makers at various levels, requiring an in-depth understanding of their motivations, incentives and barriers for participation (Wehn et al., 2016). An increasing number of studies focuses on the motivations, attitudes towards and challenges for the participation of distinct stakeholders in CBMs (e.g. Hobbs and White, 2012; Rotman et al., 2012, 2014; Wright et al., 2015; Alender, 2016; West and Pateman, 2016; Gharesifard and Wehn, 2016a, b; Geoghegan et al., 2016; Martin et al., 2016a, b; Everett and Geoghegan, 2016; Verbrugge et al., 2016; Ganzevoort et al., 2017; Dem et al., 2018). However, existing studies are often unclear about the conceptual underpinnings of key constructs such as motivation, attitudes or behaviour. This raises questions about the extent to which relevant theoretical bodies of literature from behavioural sciences have been used for examining the drivers and barriers for participation. Overall, this is limiting the extent to which the results of such work can be generalized and used to guide the implementation of CBMs.

Drawing on the Theory of Planned Behaviour (Ajzen, 1991) as an organising theoretical framework, the purpose of this paper is to help overcome the dispersion in the field and integrate the emerging results of the literature. It presents the findings a critical analysis of previous empirical research in areas of relevance i.e. participation in environment-focused Citizen Science, community-based environmental monitoring, and participatory monitoring. Distinguishing between three core stakeholders, the insights from the literature are organised and integrated to take stock of the state of research into motivations for CBM participation, to identify complementary and conflicting incentives for the respective actors, and to indicate gaps to be addressed in future research on participation in CBM.

The paper is structured as follows. In the next section, the theoretical context is set in terms of CBMs and the new forms of data collection and ICT-facilitated participation that they provide, coupled with the introduction of the organising framework, drawn from social psychology, for our critical analysis and integration. The methods section presents the approach that was taken for the literature review. The results section details the organised insights from the literature for each of the core stakeholders in CBM. In the 'Discussion' section, the findings are discussed in terms of the state of research into motivations for CBM, complementary and conflicting incentives for the respective key stakeholders in a CBM and their implications for the implementation of the SEIS pillars, as well as gaps to be addressed in future research on participation in CBM. The last section draws conclusions about CBMs as an enhancement of the initial SEIS conceptualisation and their role in helping to achieve envisaged SEIS benefits.

2. Theoretical context

2.1. CBMs and new forms of data collection

The principle of involving citizens in scientific enquiry is known as Citizen Science (Irwin, 1995), which entails distinct efforts to include and engage citizens in specific steps of the scientific method (Cooper et al., 2007; ECSA Ten Principles of Citizen Science, reported by Robinson et al., 2018), but also varying degrees of citizen control, influence and scope of activity in this process (Shirk et al., 2012). Although overlapping with Citizen Science activities, CBM initiatives (also called 'citizen observatories' (Wehn and Evers, 2015; Grainger, 2017)) are distinct in terms of their ambition to set up long term interactions with citizens as observers of their local environment, the strong link of the monitoring activities to policy (rather than primarily science), and the focus on the local scale as well as on *environmental* observation - as opposed to other disciplines of Citizen Science-based scientific enquiry as well as the many 'one off' types of citizen involvement (e.g. in Blitzes). Moreover, CBMs are also more closely liaised to both, 'bottom up' initiatives for community-based environmental management and conservation and 'top down' frameworks, such as the European Commission's Flood Directive (Directive 2007/60/EC) and the UNISDR Sendai Framework for Disaster Risk Reduction, as a means for tapping into local and indigenous knowledge of communities and strengthening their resilience.

A basic requirement, therefore, for any CBM to pan out well, is strong and sustained willingness of all of the key actors to participate - initially and over time. The key actors referred to in this context are those stakeholders who are taking part in the collective action that creates the (virtual) community of the CBM namely citizens, scientists/data aggregators and policy/decision makers (Wehn et al., 2015)

2.2. Behavioural perspective into participation in CBMs

The purpose of this paper is to review the (dispersed) empirical insights from the literature using a theoretical framework in order to generate an integrated overview of the incentives and barriers that influence the willingness of the different types of stakeholders to participate in CBM initiatives. The Theory of Planned Behaviour TPB (Ajzen, 1991), a relevant and proven decision making theory from social psychology, stipulates that a given strategic behaviour may result in advantages as well as drawbacks, may be encouraged by some institutions and favourably looked upon by peers but may be rejected by others, and may rely on a set of practical skills and circumstances (opportunities) to be actually carried out. Previous research has shown that the TPB can be used to provide insights into behaviours related to participation, such as scientists engaging with the lay public (Poliakoff and Webb, 2007), citizens engaging in marine research (Martin et al. (2016a, b), citizens sharing weather data via online platforms (Gharesifard and Wehn, 2016a, b); data sharing between organizations (Plengsaeng et al., 2014; Thu and Wehn, 2016; Wehn de Montalvo, 2003) and innovation and knowledge transfer between organizations (Wehn and Montalvo, 2018).

The TPB serves to examine the psychological foundation of human action (behaviour) which according to this theory consists of beliefs. Beliefs are thus conceived as the factors influencing one's decisions to engage (or not to engage) in a specific behaviour which is conceptualized as behavioural intention (willingness) and is assumed by the TPB to be the immediate determinant of actions. According to the TPB, those beliefs can be grouped into three categories; one of a personal nature (reflecting attitude towards the behaviour), the second reflecting the social context (social pressure) and the third reflecting contextual and circumstantial aspects (perceived behavioural control). How the TPB and its key elements can be applied to our investigation into incentives and barriers for participation in CBMs is illustrated in Fig. 1 below.

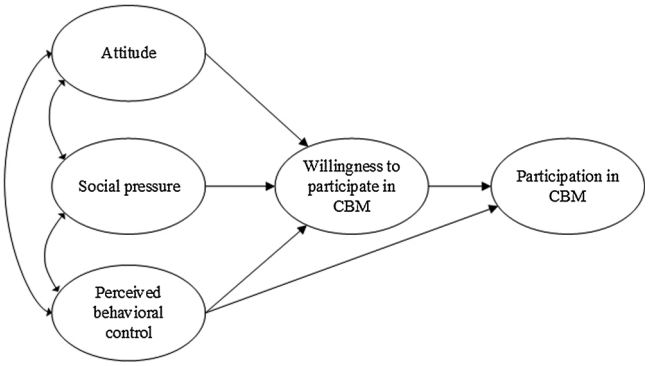

Fig. 1. Behavioural model of stakeholder participation in a CBM, based on the TPB.
Source: based on Ajzen (1991).

The three categories of beliefs (attitude, social pressure and perceived behavioural control) serve to organise our literature review, as explained below.

Attitudes towards participation in a CBM – Behavioural beliefs

Attitudes relate to one's beliefs about the possible outcomes or consequences from engaging in a specific behaviour and whether these outcomes are positive or negative (Ajzen, 1991). In the context of this paper, this relates to the stakeholders' beliefs about expected positive or negative outcomes of their involvement in a CBM.

Social pressure regarding participation in a CBM – Normative beliefs

People's actions are usually guided by social norms of what is agreeable in a group or society (Ajzen, 1991). Those norms are perceived by people as social pressure to engage in specific actions (or not). Social pressure with respect to participation in a CBM relates to the stakeholders' beliefs of whether individuals, groups or organizations important to them will be in favour or against their involvement in the CBM.

Perceived behavioural control over participation in a CBM – Control beliefs

Positive beliefs about outcomes and encouraging social pressure may not be sufficient for people to engage in a specific behaviour, it is also influenced by their beliefs about how capable they are of engaging in that behaviour due to the presence of certain factors or circumstances (i.e. resources, knowledge, opportunities) that might facilitate them engaging in the behaviour or obstacles and barriers they need to overcome (Ajzen, 1991). For this study, this refers to stakeholder beliefs regarding factors or circumstances that would help or enable their involvement in the CBM and those that would hinder or prevent their involvement.

In sum, the conceptualisation of stakeholder beliefs according to the three above-mentioned categories forms the basis of the investigation into incentives and barriers of their participation in the CBM. The combination of the positive behavioural, normative and control beliefs can be understood as the incentives whereas negative behavioural, normative and control beliefs are referred to as barriers.

2.3. Using the TPB as an organising framework for a critical analysis and integration of incentives and barriers for CBM participation

The regular application of the TPB involves a qualitative stage of research (eliciting relevant beliefs, typically via interviews), followed by a quantitative stage (measuring the strength of each belief, typically via large scale surveys using questionnaires). The quantitative stage serves well to predict whether and why respondents are (not) likely to engage in a specific behaviour whereas the qualitative stage serves to explain the drivers of a specific behaviour. The purpose of using the TPB in this paper is the latter; the TPB is used to organise the empirical insights reported in the literature to 'map' the range of relevant beliefs that may influence the willingness of the different key stakeholders to participate in CBM initiatives. This method of applying the TPB has proven to be useful in previous research for generating relevant insights (e.g. Plengsaeng et al., 2014; Thu and Wehn, 2016; Gharesifard and Wehn, 2016a, [Gharesifard and Wehn, 2016b] b; Wehn and Montalvo, 2018).

Moreover, in principle, two different perspectives related to CBM participation can be distinguished, namely individual and organisational. Belief domains for individuals (e.g. citizens) are different from those of organisations (e.g. data aggregators/scientists and policy/decision makers), since the beliefs of the former are related to personal perspectives while the latter beliefs capture a more aggregated perspective, i.e. those of a particular department or organisation, as seen through the eyes of key informants.

These domains have been identified and confirmed in previous research into related behaviours i.e. online sharing of personally collected weather data (Gharesifard and Wehn, 2016a, b), inter-organizational spatial data sharing (Wehn de Montalvo, 2003), data sharing in transboundary integrated water resources management (Plengsaeng et al., 2014; Thu and Wehn, 2016) and ICT-enabled inter-organizational knowledge transfer in the water sector (Wehn and Montalvo, 2018). The belief domains identified from the literature for these two perspectives are presented in Figs. 2 and 3, respectively.

Owing to its wide application, the TPB and its constructs have not been uncontested and distinct variations to the TPB model have been proposed over the years. Rather than rehearsing these debates here (e.g. Conner and Armitage, 1998), we refer to the most relevant outcomes of these debates for our current purpose, namely how to address moral norms, fear and past behaviour in the TPB.

Moral norms refer to a person's perception of the appropriateness or correctness (or inappropriateness and incorrectness) of performing a behaviour (Ajzen, 1991). As such, it goes beyond specific referents regularly solicited among the normative beliefs and taps into an individual's perception of how society at large perceives the behaviour in question. Although debated by some authors (see review by Manstead (2000)) whether this should be a separate construct or included among the social pressure beliefs, we concur with Ajzen (1991) to include moral norms as a source of positive or negative pressure.

Similarly, fear and past behaviour have been discussed as factors influencing the performance of a behaviour. Their precise location in the TPB has been debated by (Conner and Armitage, 1998; Ouellette and Wood, 1998). We argue that fears related to stakeholder participation in CBM can be captured as part of the expected negative outcomes of performing the behaviour. Similarly, past experience informs expectations regarding the positive or negative outcomes of performing a behaviour. This is in line with earlier findings that the separate construct of past behaviour lacks explanatory value (Ajzen, 2002).

3. Methodology

The literature review of incentives and barriers for participation in CBM consisted of four distinct steps.

In step 1, the Web of Science was used to identify relevant peer-reviewed journal articles, conference papers, book chapters and books published since 1990. The keywords for this search are shown in Box 1. The search generated 319 hits. In addition, two relevant technical reports received within the authors' professional networks were also included. The final selection of papers for the review was based on the following criteria: a) thematic focus of CBM with relation to the environment, b) involvement of citizens in monitoring, and c) empirical evidence about one or more of the core CBM stakeholders. In total, 120 publications and reports were included in the initial analysis.

In step 2, the MaxQDA software was set up for coding the collected secondary material. A coding structure was set up according to the TPB

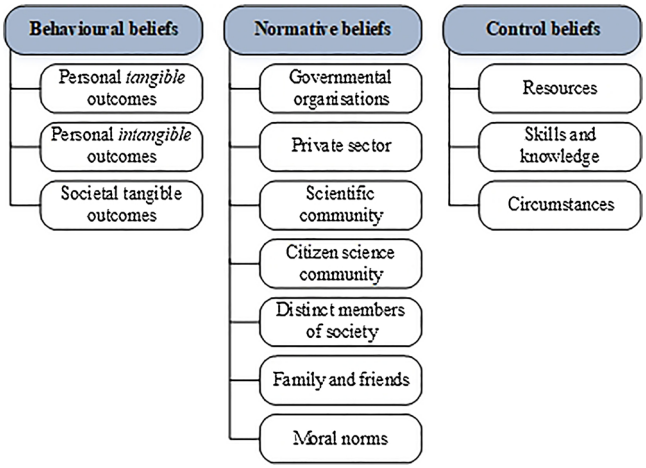

Fig. 2. Literature-based belief domains of individuals re. their participation in a CBM.
Source: based on Gharesifard and Wehn (2016a,b) .

categories of beliefs (behavioural, normative and control beliefs) and the subsets of detailed belief domains within each of these categories elaborated in Section 2 (see also Figs. 2 and 3).

In step 3, the two authors divided the total set of papers in half for coding, each author coding half. The studies were analysed to elicit beliefs (behavioural, normative, and control beliefs) for each of the core CBM stakeholders separately (citizens, scientists/data aggregators and policy/decision makers). Identified beliefs were placed in the appropriate belief domain. Beliefs that did not fit within existing belief domains were grouped into additional belief domains. Groups of related beliefs within a domain were placed into clusters. In this step, a number of papers were excluded from the analysis to ensure consistency in the sample and alignment with the TPB according to the following criteria: if the paper reported empirical material but the evidence did not represent the perspectives of involved stakeholders (views, opinions, perception); the paper did not allow for clear attribution of beliefs to specific stakeholders (e.g. due to more general discussions of issues); the evidence consisted of beliefs about others (e.g. scientists' opinions of what motivates citizens) or the reported evidence was not related to an environmental CBM. This reduced the set of papers to 42 for the detailed analysis. In total, more than 1200 items were coded in the papers.

In step 4, the authors merged the coded beliefs and cross-checked each other's categorizations. A small number of beliefs were then moved to the jointly agreed category. The overall coding structure was reviewed and adjusted (e.g. some of the newly created belief domains and clusters were merged).

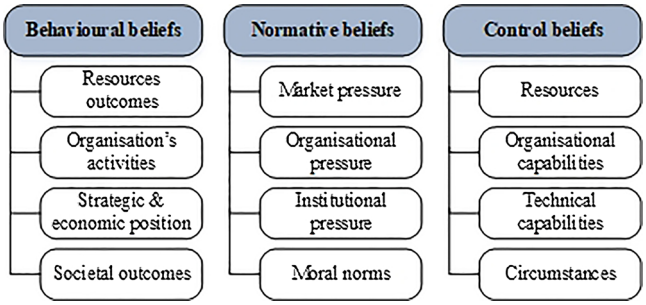

Fig. 3. Literature-based belief domains of organisations re. their participation in a CBM.
Source: based on (Plengsaeng et al., 2014; Thu and Wehn, 2016; Wehn de Montalvo, 2003, Wehn and Montalvo, 2018).

4. Results

4.1. State of the field: research into participation in CBMs

The papers in this review cover a wide range of different geographical areas (countries on five continents, see Table 1) and as such, this coverage presents somewhat more balance than the lack of attention to initiatives outside North America observed by Johnson et al. (2014). The thematic monitoring topics in these papers (Table 2) range from biodiversity, ecology and water quality to noise, phenology and the human-wildlife conflict. The largest number of studies reports on CBMs in biodiversity monitoring (14 papers), similar to what Kullenberg and Kasperowski (2016) found for Citizen Science more generally.

The timing of the publication dates of papers on stakeholder motivations indicates the emergent nature of this field (see Fig. 4), with the first paper on the topic (among the reviewed papers) published in 2001, followed by an explosion of publications in 2015, this expansion of publications follows the trend observed for the field of Citizen Science more generally in the scientometric meta-analysis by Kullenberg and Kasperowski (2016). This covered publications until 2015 and found that, at the time, motivations for participation in Citizen Science were under-researched.

The papers in our sample covered the stakeholders of interest, as indicated in Table 3. By far the largest number of the papers focused on *citizen* participation (36 out of the 42 publications), compared to only 10 out of 42 papers covering stakeholders such as scientists, data aggregators and policy/decision makers. Only 12 studies covered more than one stakeholder. Contrary to the claim by Alender (2016) and Jollymore et al. (2017) that the motivations of citizens to participate have been covered less by the literature than the perspective of scientists, our findings indicate the opposite: the majority of the papers in our sample (which were selected based on their provision of primary empirical evidence and clear attribution of beliefs to specific stakeholders) report on motivations of citizen, not those of scientists, nor those of policy/decisions makers.

In terms of the conceptual and methodological design of reviewed studies, we found that only 21 papers (50%) presented some detail on the concepts and/or methodology used by the authors for their empirical data collection on incentives and barriers for stakeholder participation.

Only 11 studies mentioned explicitly which specific theories or relevant concepts they based their research on: Volunteer Functions Inventory based on the functional approach to motivation, used by Cox et al. (2018), Wright et al. (2015) and Ferster et al. (2013); the social movement participation model and self-determination theory used by Nov et al. (2014) ; Reasoned Action Approach/TBP used by Martin et al. (2016a), TPB used by Martin et al. (2016b) and Gharesifard and Wehn (2016a, b), and systems thinking used by Vann-Sander et al. (2016). Yet these papers vary considerably in the level of detail provided on how the selected theory had informed their inquiry and shaped the design and implementation of their instruments and subsequent analysis.

Furthermore, with few exceptions, most of the papers that merely referred to previous studies as the basis for the design of their instrument (e.g. questionnaires, interview protocols), did not reference the studies whose methodologies they stated to be using.

These findings on the conceptual and theoretical grounding and the methodological aspects of the reviewed papers point to a weakness in the scientific quality of the existing research in the field of motivations for participation in CBM. In many studies, this weakness is hampering the replicability of the presented results and the assessment of validity of the respective findings.

4.2. Incentives and barriers for citizen participation in a CBM

The stakeholder category 'citizens' includes a number of actors: trained as well as untrained members of the general public who participate individually or through organized groups e.g. hobby groups, activists groups, community action groups etc. Their participation in a

Box 1
Boolean search string used for the identification of relevant literature.

('citizen observatory' OR *'citizen observatories'* OR *'citizen science'* OR *'community based monitoring'* OR *'volunteer environmental monitoring'* OR *'participatory monitoring'* OR *'volunteered geographic information'* OR *'crowdsourcing geospatial data'* OR *'people-centric sensing'* OR *'participatory sensing'* OR *'community science'* OR *'collaborative science'* OR *'collaborative monitoring'* OR *'participatory research')* **AND** *('motivation'* OR *'incentive'* OR *'driver'* OR *'obstacle'* OR *'barrier'* OR *'challenge'* OR *'deterrent'* OR *'attitude'* OR *'bottleneck')*

Table 1
Overview of the geographic focus of monitoring scheme covered in the reviewed studies.

Geographic focus	No. of papers*
North America*	16
Europe	15
Australia	9
Asia	6
Africa	4
Central America	2

Table 2
Overview of the thematic focus of monitoring scheme covered in the reviewed studies.

Thematic focus	No. of papers*
Biodiversity	14
Ecology	6
Water quality	5
Disaster management	5
Weather & climate	4
Marine	4
Natural resources management	3
Phenology	1
Built environment	1
Noise	1
Industrial development	1
Human-wildlife conflict	1

* Some papers covered more than one topic and/or country.

CBM can take many forms, i.e. defining research questions, collecting data or observations on certain phenomena either manually or through portable devices, sensors, devices, smart phones or tablets, sharing collected data and observation through mobile applications, social media or web-platforms, checking or verifying and sometimes analysing shared data. For organized citizen groups such as community action groups, amateur and hobby groups, participation can also include recruiting and training new participants.

Given that most of the reviewed papers focused on the incentives and barriers of citizens (rather than any of the other stakeholders of interest), the range and set of beliefs potentially influencing citizen participation is also the most detailed.

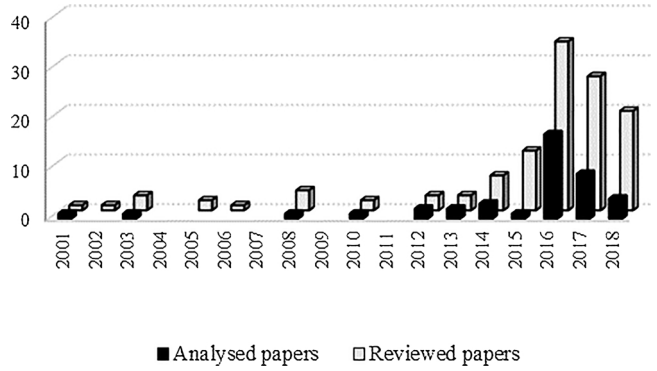

Fig. 4. Number of publications per year on stakeholder motivations to participate in SEIS.

4.2.1. Behavioural beliefs of citizens re. CBM participation

These beliefs represent citizens' perception of the possible outcomes or consequences of performing the activities mentioned above. These outcomes identified from the literature (see Fig. 5) were categorized as either positive or negative and grouped into the following three domains:

1 **Tangible outcomes:** refer to the actual or approximate gains and losses that a person perceives to obtain as the result of their participation in the CBM.
2 **Intangible outcomes:** refer to intrinsic gains in the form of self-actualization or inner satisfaction that one may gain as the result of participation in the CBM.
3 **Social outcomes:** refer to the positive and negative implications for their community, society at large and the public good which could result from one's participation in the CBM.

In the tangible personal outcomes domain, positive beliefs span from participating in a CBM for fun and entertainment, interest in the technology (software, camera), to concrete financial rewards or obtaining data (e.g. for own outdoor activities), to creating career opportunities (e.g. via enhanced CV or contacts made). Beliefs in this domain about negative outcomes relate to concerns about malicious or commercial use of the provided data, concerns about the quality or accuracy of the provided data, implications for the citizen's own privacy and security (e.g. disclosure of personal property) or worries about restrictions that could be imposed (e.g. to fishing or property) as a result of provided data, and, finally, to one's efforts simply not being worthwhile (waste of time).

Perceived intangible outcomes range from a personal, to the collective and even a societal level: learning and expanding own skills, but also expecting personal attribution, recognition or even a certificate of participation (personal level); being motivated by the socializing elements of spending time with like-minded people, obtaining a sense of belonging to a community, and sharing knowledge (collective level); and/or sense of achievement by doing something useful and for a greater purpose (societal level). Compared to this range of expected positive intangible outcomes from participation, in the reviewed literature, the only negative intangible outcome perceived by citizens consists of a lack of recognition for their participation efforts.

Beyond these outcomes relating to the citizen themselves, the literature suggests a range of expectations about positive societal outcomes that can drive citizen participation. These range from greater citizen representation in decision making, to improving science and scientific knowledge, socio-economic development and environmental conservation. At the same time, various opposing beliefs have also been identified, mirroring many of the positive expectations above, namely: lack of influence in decision making, concerns about erroneous decisions that can result from misinterpretation of citizen data, widening the digital divide for technology-reliant CBMs, or harming (rather than protecting) rare species or locations in the environment.

4.2.2. Normative beliefs of citizens re. CBM participation

Normative beliefs represent the perceptions of citizens of how other important individuals, groups or organizations conceive their participation in a CBM, and whether these individuals or organisations **approve or disapprove** of it. According to perceptions of citizens, those 'key referents'

Table 3
Overview of specific CBM stakeholder(s) addressed in the analysed papers (Alendar, 2016; Aristeidou et al., 2017; Baruch et al., 2016; Burgess et al., 2017; Domroese and Johnson, 2017; Haworth, 2016; Haworth et al., 2016; Jansujwicz et al., 2013; Koss and Kingsley, 2010; Larson et al., 2016; Liu et al., 2018; Mitchell et al., 2017; Olteanu-Raimond et al., 2017; Reinhardt and Heinig, 2016; Rosas et al., 2016; Ryan et al., 2001; Williamson et al., 2016; Wiseman and Bardsley, 2016; Yarnell and Gayton, 2003).

#	Stakeholders covered in the study	C	S/DA	P/DM	#	Stakeholders covered in the study	C	S/DA	P/DM
1	Alendar, 2016	**0**			22	Koss and Kingsley, 2010	**0**		
2	Aristeidou et al., 2017	**0**			23	Larson et al., 2016	**0**		
3	Baruch et al., 2016	**0**	**0**		24	Liu et al., 2018	**0**	**0**	
4	Burgess et al., 2017		**0**		25	Lucrezi et al., 2018	**0**		
5	Conrad and Daoust, 2008	**0**			26	Martin et al., 2016a	**0**		
6	Cox et al., 2018	**0**			27	Martin et al., 2016b	**0**		
7	Dem et al., 2018	**0**			28	McKay and Johnson, 2017	**0**		**0**
8	Domroese and Johnson, 2017	**0**			29	Mitchell et al., 2017	**0**		
9	Everett & Geoghegan, 2016	**0**			30	Nov et al., 2014	**0**		
10	Ferster et al., 2013	**0**		**0**	31	Olteanu-Raimond et al., 2017			**0**
11	Ganzevoort et al., 2017	**0**			32	Reinhardt and Heinig, 2016	**0**		
12	Geoghegan et al., 2016	**0**	**0**	**0**	33	Rosas et al., 2016	**0**		
13	Gharesifard and Wehn, 2016a	**0**			34	Rotman et al., 2012	**0**	**0**	
14	Gharesifard and Wehn, 2016b	**0**			35	Rotman et al., 2014	**0**	**0**	
15	Haworth, 2016			**0**	36	Ryan et al., 2001	**0**		
16	Haworth et al., 2016	**0**			37	Vann-Sander et al., 2016	**0**	**0**	**0**
17	Hobbs and White, 2012	**0**	**0**		38	Verbrugge et al., 2016	**0**		**0**
18	Jansujwicz et al., 2013	**0**		**0**	39	Williamson et al., 2016	**0**		
19	Johnson et al., 2014	**0**			40	Wiseman and Bardsley, 2016			**0**
20	Jollymore et al., 2017	**0**	**0**		41	Wright et al., 2015	**0**		
21	Kinchy, 2017	**0**		**0**	42	Yarnell and Gayton, 2003		**0**	

C = Citizens; S/DA = Scientists/Data aggregators; P/DM = Policy/Decision makers.

exert positive or negative pressure for citizen participation in a CBM.

Based on the findings from the literature, public sector organisations, the private sector, the scientific community, and family members and friends can contain both, key referents in favour or against citizen participation (see Fig. 6). Members of the Citizen Science community appear – not surprisingly perhaps - only as a referent in favour of citizen participation in a CBM. Similarly, moral norms were listed only as a source of positive social pressure, in favour of citizen participation. Employers were noted as a potential source of pressure against citizen participation (e.g. due to inflexibility).

In general, it is important to note that this category of beliefs is highly dependent on the thematic focus of the CBM and the specific context. These are thus less easily extracted from secondary data or only in the general stakeholder denominations above. In addition, very few beliefs were found in the reviewed literature for this category which highlights the strength of the TPB in tapping into previously un-explored aspects in the field of CBM participation.

4.2.3. Control beliefs of citizens re. CBM participation

Control beliefs concern citizens' beliefs about the presence of factors that may **facilitate or hinder** their data collection activities, data sharing and other activities related to their participation in the CBM. Two groups of control factors can be distinguished based on their relation to the individual or group of individuals performing the behaviour; internal and external factors (Ajzen and Madden, 1986). The results presented in Fig. 7 are grouped into domains as the follows:

Internal factors

1) **Resources**: relates to the (un)availability of the resources needed for participation in the CBM
2) **Skills and knowledge**: relates to the presence or absence of specific technical skills of the individual (or group of individuals) that are needed to participate in the CBM and to the presence or absence of general knowledge related to the topic of the CBM.

External factors

3) **Circumstances:** relates to the circumstantial factors that are not required for participation in the CBM but whose presence/absence might serve to facilitate or impede participation, respectively.

The identified beliefs relating to the internal factors (resources and skills & knowledge) came up as either incentives (i.e. if the resources/skills are present) or barriers (i.e. if the respective resource/skill is lacking). Resources necessary for citizen participation identified in the literature consist of time and financial resources, but also technical infrastructure such as IT equipment, internet connection and monitoring equipment. Time has often been mentioned as the most important resource and lack of time a main reason for not participating or dropping out. Technical skills to use the above infrastructure elements as well as domain-specific knowledge related to the topic of observation of the CBM can equally be facilitators (if present) or inhibitors (if absent).

Regarding the external factors that have been identified in the literature, a more diverse picture emerged. Facilitating factors such as gamification and competition and the presence of data and privacy policies directly correspond to the expected outcomes identified above (i.e. expecting fun and entertainment but also privacy concerns) among the behavioural beliefs. Similarly, clear instructions, training and professional support as perceived facilitating factors correspond to concerns about citizen participation resulting in misinformed decisions or interventions. Features of the technologies involved in the CBM came up as both, facilitating and hindering citizen participation. The much discussed notion of involving citizens beyond data collection is reported as a facilitating aspect. Similarly, providing feedback to citizens in return for their involvement is perceived facilitating participation if it consists of

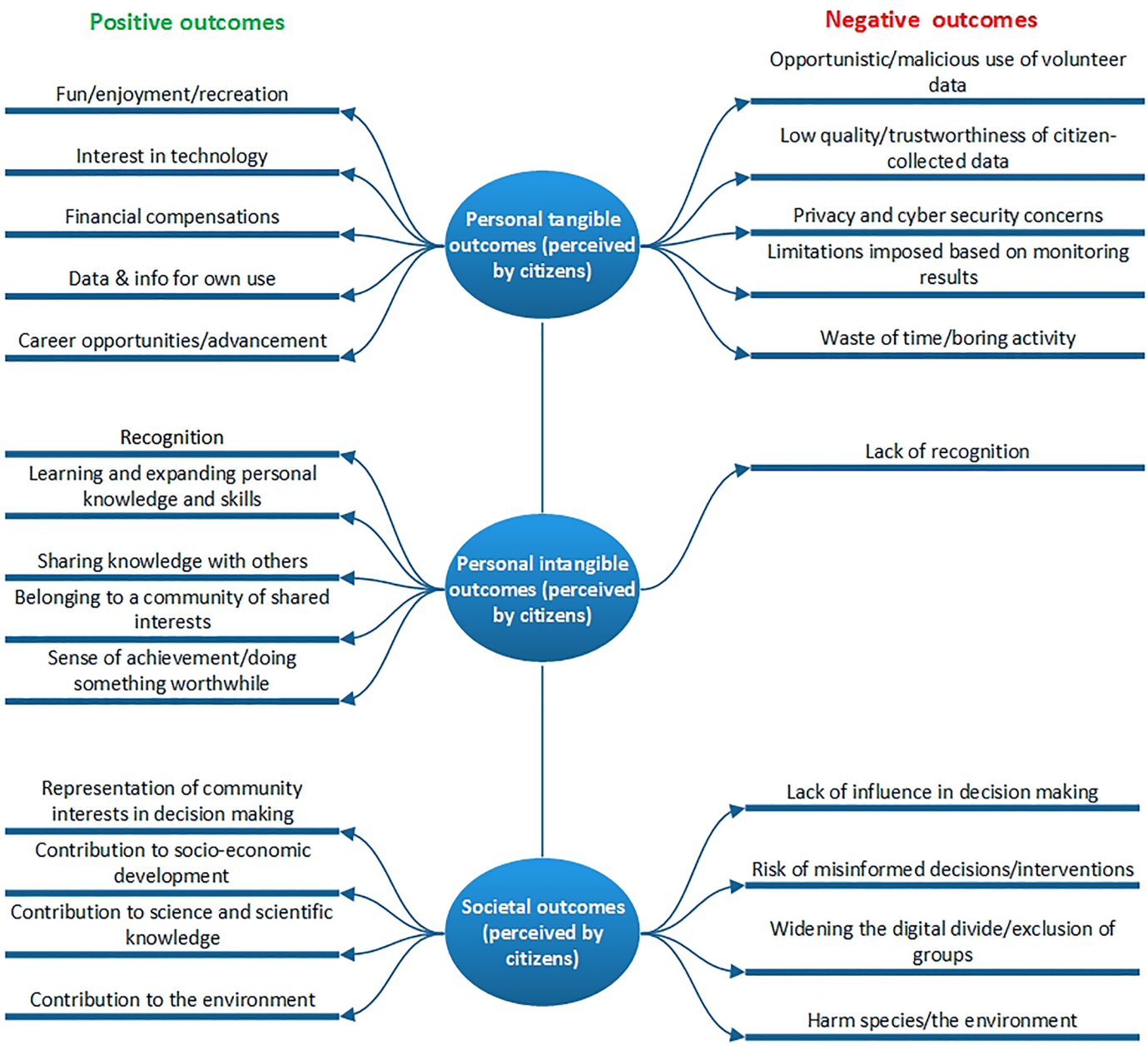

Fig. 5. Overview of behavioural beliefs of citizens re. CBM participation.

information about the quality of the provided data, of processed results, or clarity about the use or impact of the citizen contributions.

Identified beliefs that allude to factors hindering participation pertain to the lack of available information about the existence of a CBM, cultural differences (e.g. between local participants and foreign scientists), to gamification or competition as deterrents for some demographic groups, lack of standardized monitoring protocols, the in-situ conditions during data collection (e.g. perceived as dangerous sites or unpleasant weather), and finally demographic conditions such as old age or poor health.

4.3. Incentives and barriers for scientists/data aggregators to participate in a CBM

The scientists/data aggregators stakeholder category includes scientists working at universities, academic or applied research institutes. It also includes commercial providers of data fusion and web platforms and mobile app service providers (for-profit as well as not-for-profit organizations).

Their participation involves using CBM data and outcomes for research or education, providing data to the CBM by sharing their own data sets, or validation, curation and processing of CBM data sets, interpreting and visualizing data (making sense of the data). They may also participate in managing the CBM platforms or be involved in activities related to managing the CBM initiative i.e. finding, recruitment of participants, training of volunteers and so on.

4.3.1. Behavioural beliefs of scientists/data aggregators re. CBM participation

Behavioural beliefs of scientists'/data aggregators consists of their evaluation of the outcomes or consequences of performing the activities mentioned above. Our findings on this category of beliefs are listed in Fig. 8 and grouped into 4 domains:

1) **Resources outcomes:** refers to the beliefs about the direct implications on the organization's resources i.e. time, expenses, staff, and administrative efforts as a result of its participation in the CBM and the perception whether these resources will be enhanced or reduced.
2) **Organisation's activities:** refers to beliefs about the implications of participation in the CBM on the organisation's core activities and

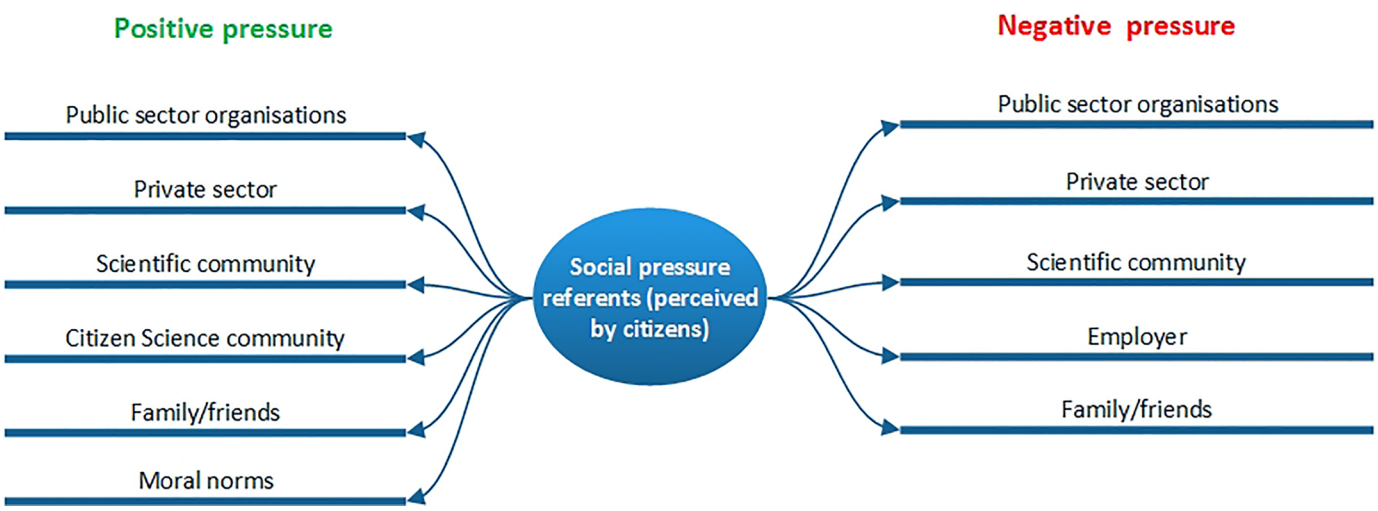

Fig. 6. Overview of normative beliefs of citizens re. CBM participation.

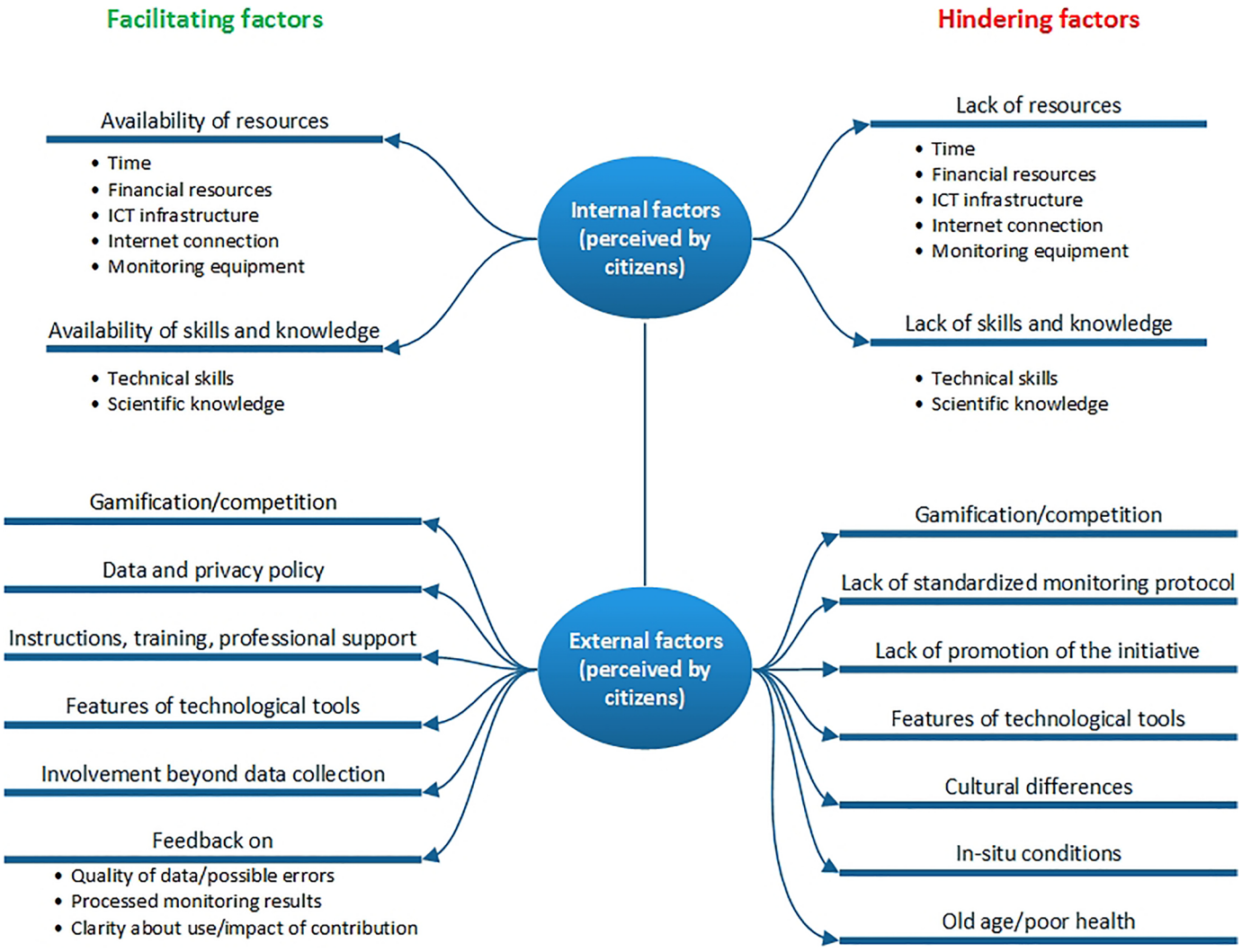

Fig. 7. Overview of control beliefs of citizens re. CBM participation.

whether it will have a positive or negative effect on the organisations' performance.

3) **Strategic position:** refers to the implications on inter-organisational relations, strategic or competitive position.
4) **Social outcomes:** beliefs about societal implications of participation in the CBM in terms of the advantages and disadvantages of CBM participation for society or the public good.

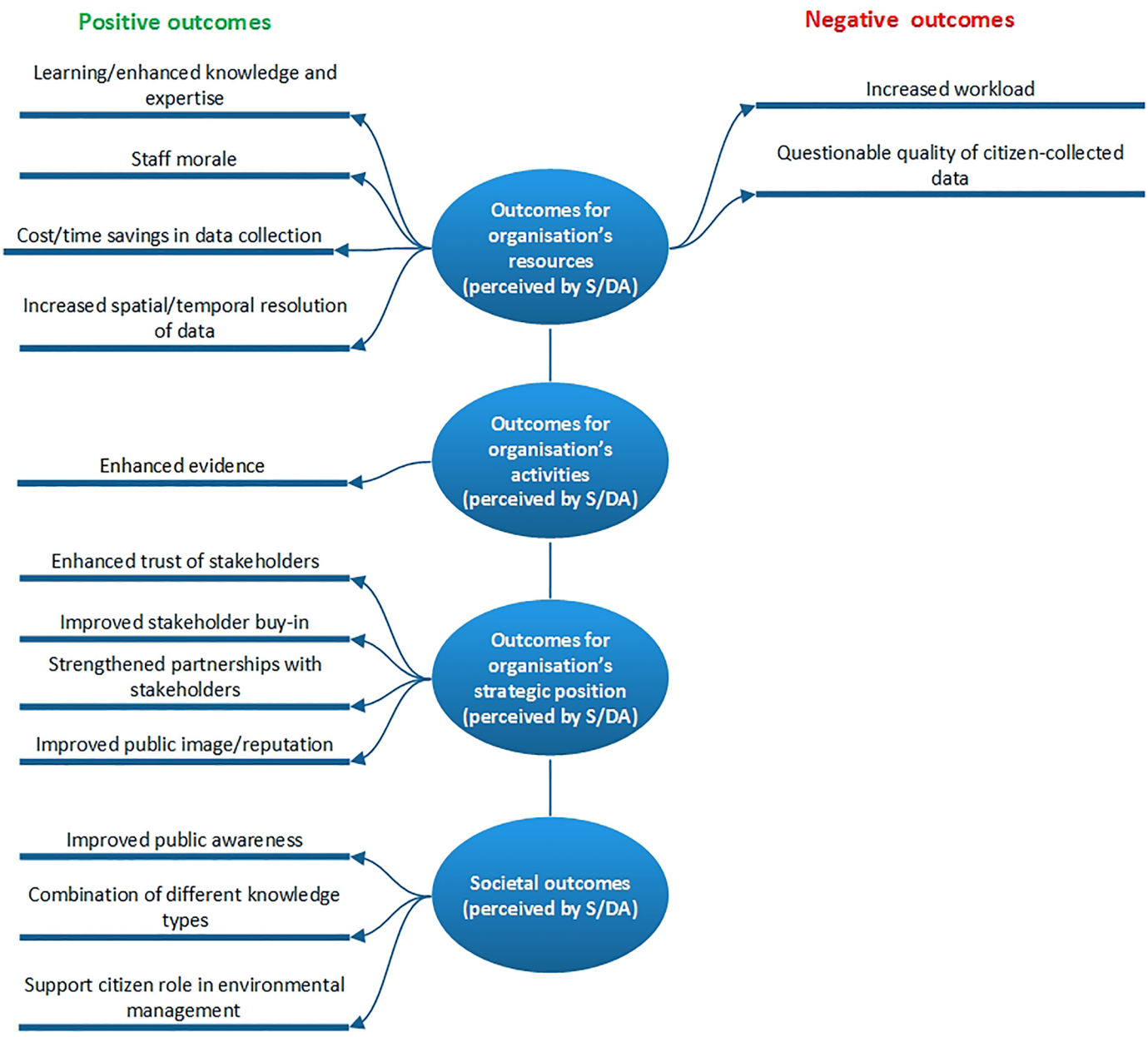

Fig. 8. Overview of behavioural beliefs of scientists/data aggregators re. CBM participation.

From the perspective of scientists/data aggregators, in terms of their organisation's resources, the literature points to both, positive and negative perceived outcomes: expected savings (in cost and time) for data collection and improvements in spatial and temporal resolution of the data but, equally, a potential increase in workload related to their participation in a CBM and questionable quality of citizen-collected data. Further positive perceived outcomes for their organization's resources is related to learning and enhanced staff expertise from their participation (e.g. gaining a different perspective about their work) as well as improved staff morale.

Regarding their organisation's activities, the reviewed literature points to positive perceptions of scientists/data aggregators regarding the generation of enhanced evidence, e.g. for reporting against targets and informing policy making. Notably, no negative perceived outcomes in this domain were identified in the literature.

At a more strategic level of their organisation, the literature has identified a number of beliefs of scientists'/data aggregators about the implications of their participation in a CBM, namely potential enhancement of stakeholders trust, improvement of stakeholder buy-in, strengthened partnerships and improvements of their organisation's public image or reputation. Again, there is no empirical evidence mentioned in the reviewed literature concerning equivalent negative perceived outcomes in this domain.

Finally, in terms of societal outcomes, the beliefs of the scientists/data aggregators stakeholder category reported in the literature point to expectations about their CBM participation resulting in improved public awareness, the combination of different types of knowledge and supporting citizens' roles in environmental management and governance. Once again, the literature does not report any negative expected outcomes in this domain.

4.3.2. Normative beliefs of scientists/data aggregators re. CBM participation

Normative beliefs concern the perceived expectations of important referents and whether these are likely to approve or disapprove of the organisation's participation in a CBM, creating social pressure on the organisation to participate in a CBM (or not). Our findings in this category of beliefs are listed in Fig. 9 and are grouped into four domains:

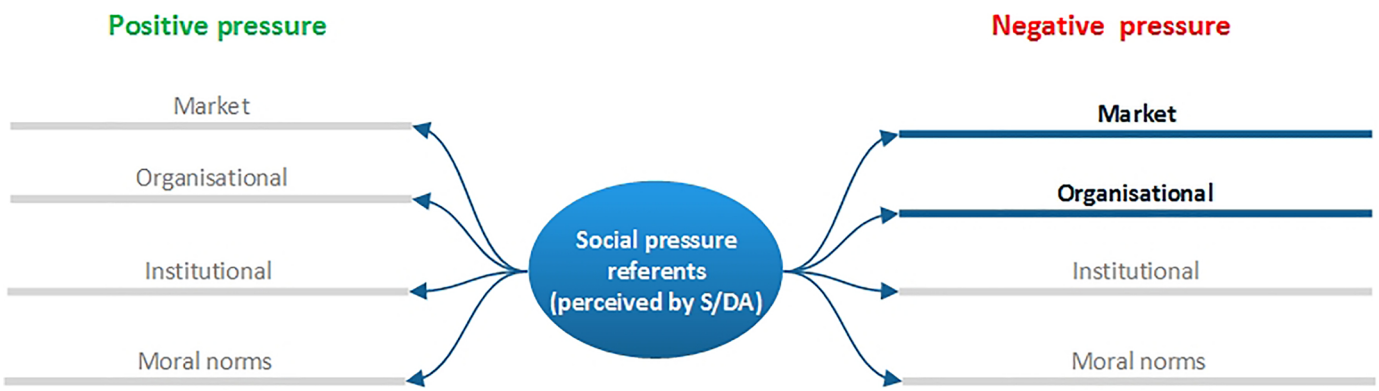

Fig. 9. Overview of normative beliefs of scientists/data aggregators re. CBM participation.

1) **Market pressure:** in competitive settings, this includes commercial, public and private data or service providers. In non-competitive settings, economic pressure can arise from concerns about the organisation's image and influence (Wehn and Montalvo 2016, Wehn and Montalvo, 2018).
2) **Organisational pressure:** relates to sources of pressure internal to the organisation, originating from the organisational hierarchy and administration such as other departments in the organisation, management of the organisation, particular individuals within the organisation and/or the organisation's mandate.
3) **Institutional pressure:** relates to the sources of pressure originating from other institutions or external policies.
4) **Moral norms:** relates to moral principles of conduct perceived to be in favour or against CBM participation.

As mentioned above, the beliefs in this category are case- and context-specific; therefore, not many salient beliefs could be extracted from secondary data. We distinguish those from domains identified in earlier, related TPB-based studies (Wehn de Montalvo, 2003; Plengsaeng et al., 2014; Thu and Wehn, 2016; Gharesifard and Wehn, 2016a, 2016b; Wehn and Montalvo, 2018). Together, these provide a general sense of the anticipated sources and directions of pressure for scientists/data aggregators to participate in a CBM. Specific findings of beliefs in the literature point to perceived negative market pressure such as competing CBM initiatives or disapproval of their participation by scientific peers and negative organisational pressure from senior management, not accepting citizen-sensed data as a scientifically sound.

The fact that few normative beliefs could be identified in the literature cannot be interpreted as non-existence of such dynamics. Rather, it may be due to the approaches used to generate empirical evidence about stakeholder motivations to participate in a CBM which – as argued above – suffer from specific weaknesses.

4.3.3. Control beliefs of scientists/data aggregators re. CBM participation

Control beliefs capture the perceived presence or absence of factors that can facilitate or inhibit organisations activities pertinent to participation in the CBM. The findings on these beliefs pertaining to scientists/aggregators are listed in Fig. 10 and grouped in the following domains:

1) **Resources**: relates to presence or absence of requisite resources such as available staff, finance, etc.
2) **Technical capabilities**: technical competencies needed to perform the activities for the organisation to participate in the CBM, such as IT skills, metadata skills, scientific subject knowledge and expertise, etc.
3) **Organisational capabilities**: knowledge and expertise needed by the organisations in its interactions with other stakeholders, such as data sharing and knowledge transfer skills, networking and negotiating skills, and skills for interacting with the public.
4) **Circumstances:** the presence or absence of circumstantial factors that are not a requisite to perform the needed activities but which can facilitate or impede CBM participation, i.e. coordination agreements between stakeholders, regulations, protocols or guidelines, or restricting laws and legal mandates, etc.

In terms of the availability or absence of resources for scientist/data aggregator's participation in CBM, the reviewed studies point to staff, time and funding-related resources as both, enablers and barriers. Organisational capabilities that are reported in the literature as relevant pertain to volunteer management skills (to maintain their interest), which can equally help (if present) or hinder (if absent). Various technical capabilities (from an IT perspective) also emerged as relevant.

With respect to circumstances that are perceived to facilitate or hinder scientist/data aggregators' CBM participation, the literature review points to a range of perceived facilitating factors, namely common interests among stakeholders in terms of environmental management and protection; communication opportunities with citizens/volunteers (e.g. F2F, via the media and social media); and the opportunity to have training for the volunteers. The latter may be closely related to their beliefs concerning data quality. In terms of dynamic, the lead role of scientists in a CBM was reported as a perceived facilitating factor as well as standardization of data collection methods and the availability and application of quality assessment/quality control procedures and frameworks. Finally, the existence of partnerships was reported to be perceived as enabling their CBM participation, e.g. ensuring that data serves to fill important gaps, serving mutual interests and increasing their publication potential. On the other hand, conflict of interest between scientists and volunteers in terms of the focus and scale of monitoring (research questions) was reported as a perceived hindering factor for the participation of scientists. The level of volunteer commitment was another hindering factor for scientists which may be related to the misalignment of monitoring interests between citizens and scientists.

4.4. Incentives and barriers for policy/ decision makers to participate in a CBM

The policy/decision maker stakeholder category includes decision making and policy setting bodies related to the environmental issue in focus of CBM. Depending on the case, this could be the local, regional or even central government departments, city councils, administrative units or municipal planning departments. Their participation in the CBM can take many forms. They can be involved in the management of the CBM, users of the CBM outcomes for evidence- based policy, for daily management or for long term planning. Their participation can also include sharing their own data sets via the CBM.

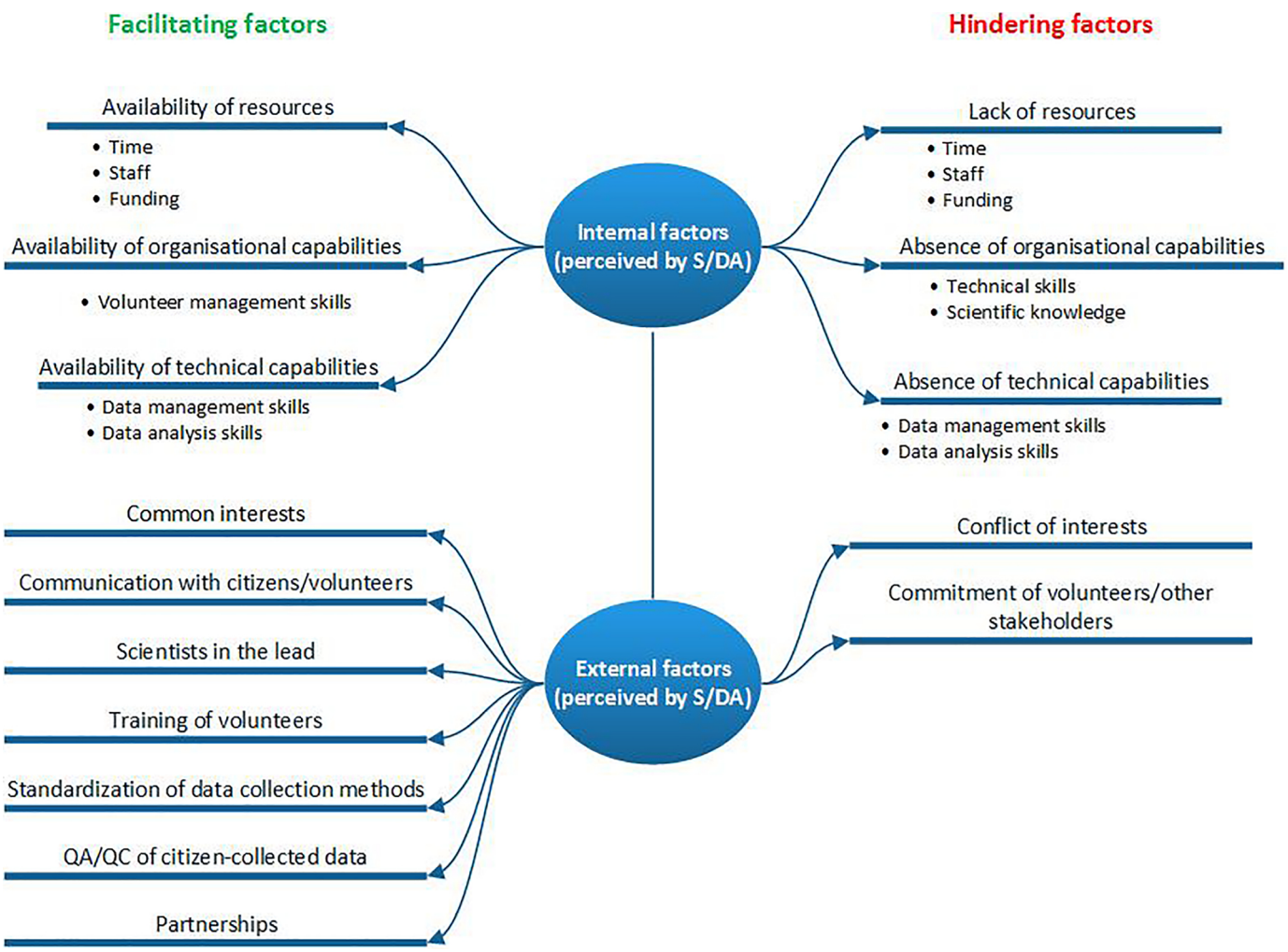

Fig. 10. Overview of control beliefs of scientists/data aggregators re. CBM participation.

4.4.1. Behavioural beliefs of policy/decision makers to participate in a CBM

Beliefs of this type of stakeholder about the outcomes or consequences of their participation in the CBM are listed in Fig. 11 and grouped into the domains explained in Section 3 (for the organisational stakeholder perspective). As for the scientist/data aggregator stakeholders, the number of papers focusing on this particular actor is very limited.

The perceived positive outcomes for the organisation's resources reported in the literature for the policy/decision makers are very similar to those reported for the scientists/data aggregators (learning, staff morale, costs/time savings and increased spatial/temporal resolution of the data). Negative consequences for their resources are reportedly expected in terms of questionable quality of citizen-collected data and in terms of an increased workload (both the same as for scientists/data aggregators).

Regarding the expected outcomes of their CBM participation for their organisation's activities, the beliefs reported for the policy/decision makers refer to enhanced communication with the public as well as enhanced decision making. No negative beliefs were identified in the literature in this domain.

The beliefs regarding outcomes for their organisation's strategic position overlap largely with those of the scientists (enhanced stakeholder trust and buy in and strengthened partnerships). Negative consequences were reported in terms of expected loss of power/control, e.g. in the production and handling of information (without professional interpretation of results) but also in terms of relying on communities more for their own resilience. Unlike the scientists/data aggregators, this group of stakeholders perceived negative outcomes for their organisation's image/reputation resulting from their participation in a CBM.

With respect to expected positive societal outcomes, the beliefs reported for policy/decision makers also include improved public awareness (as for scientists) but also expectations regarding an enhanced sense of stewardship of the community as well as positive outcomes in terms of socio-economic development more broadly. In the other direction, negative beliefs in this domain consist of concerns about the resulting decisions being biased, e.g. towards industry solutions, or because of volunteer groups that are unrepresentative of the population.

4.4.2. Normative beliefs of policy/decision makers re. CBM participation

Our findings on the normative beliefs and the perceived sources of social pressure regarding the participation of policy/decision makers in a CBM are listed in Fig. 12. As mentioned before, this category of beliefs is very case-dependent; also, relevant secondary data sources were very limited, pointing to a gap in the literature. The results presented here provide both, a general sense of the anticipated sources and directions of pressure (in regular font) for policy/decision makers to participate in a CBM (market, organizational and institutional pressures as well as moral norms) as well as the specific identified beliefs (in bold). Positive pressure were reported to consist of moral norms perceived as obliging policy/decision makers to help communities in some way in return for their monitoring activities, negative pressure were reported to stem from legislation and restrictions in the use of various types of information (i.e. including citizen-sensed data).

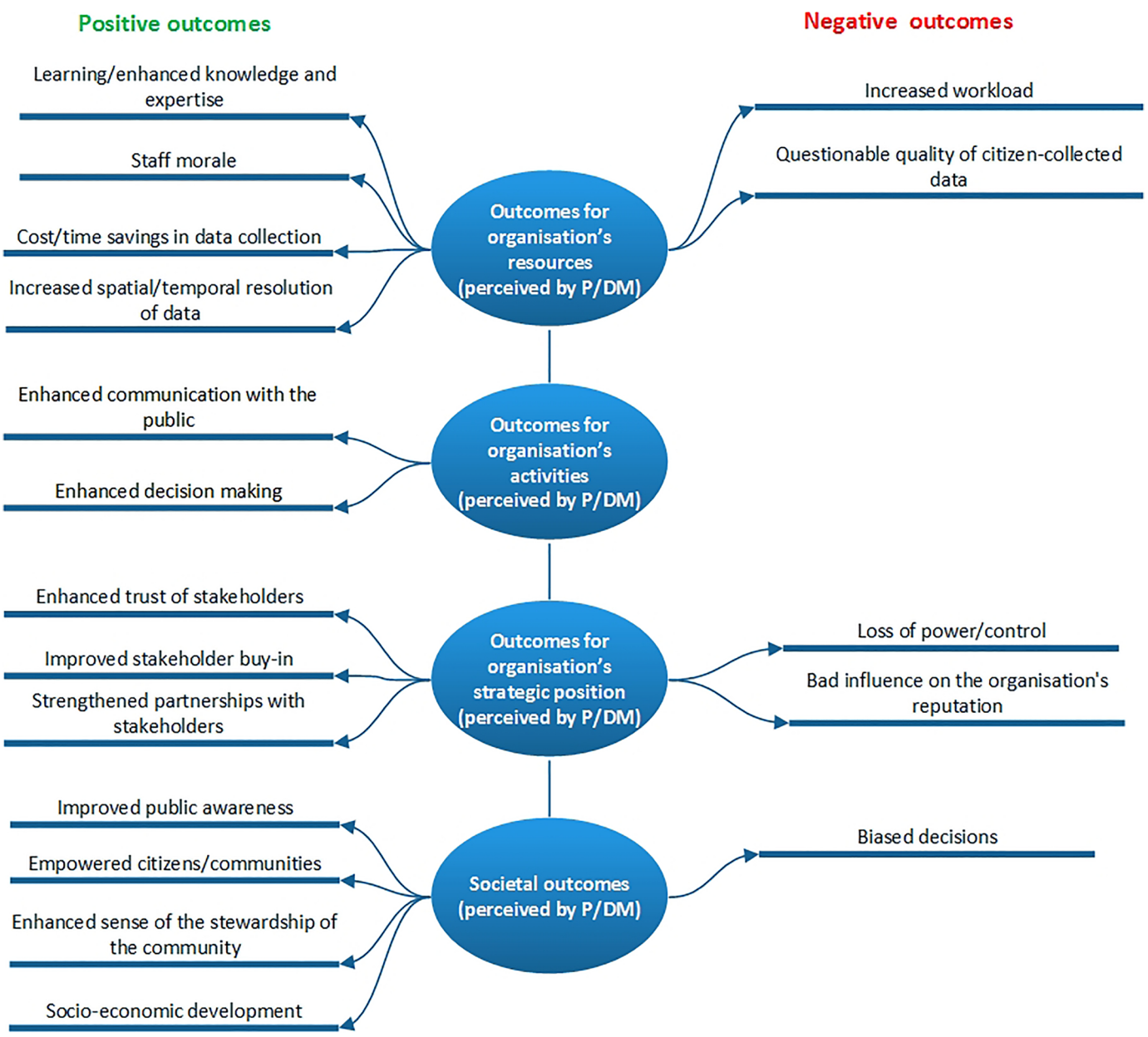

Fig. 11. Overview of behavioural belief domains of policy/decision makers re. their CBM participation.

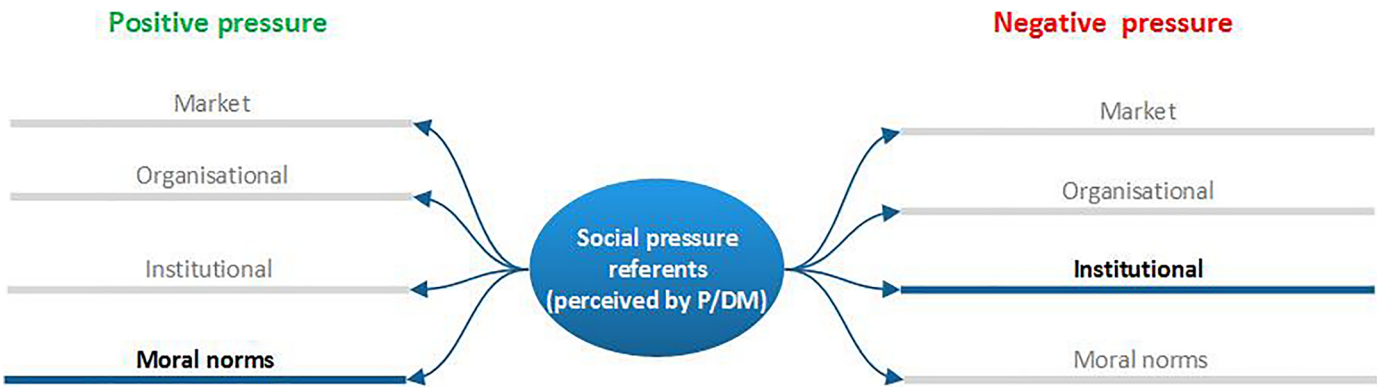

Fig. 12. Overview of normative beliefs of policy/decision makers re. CBM participation.

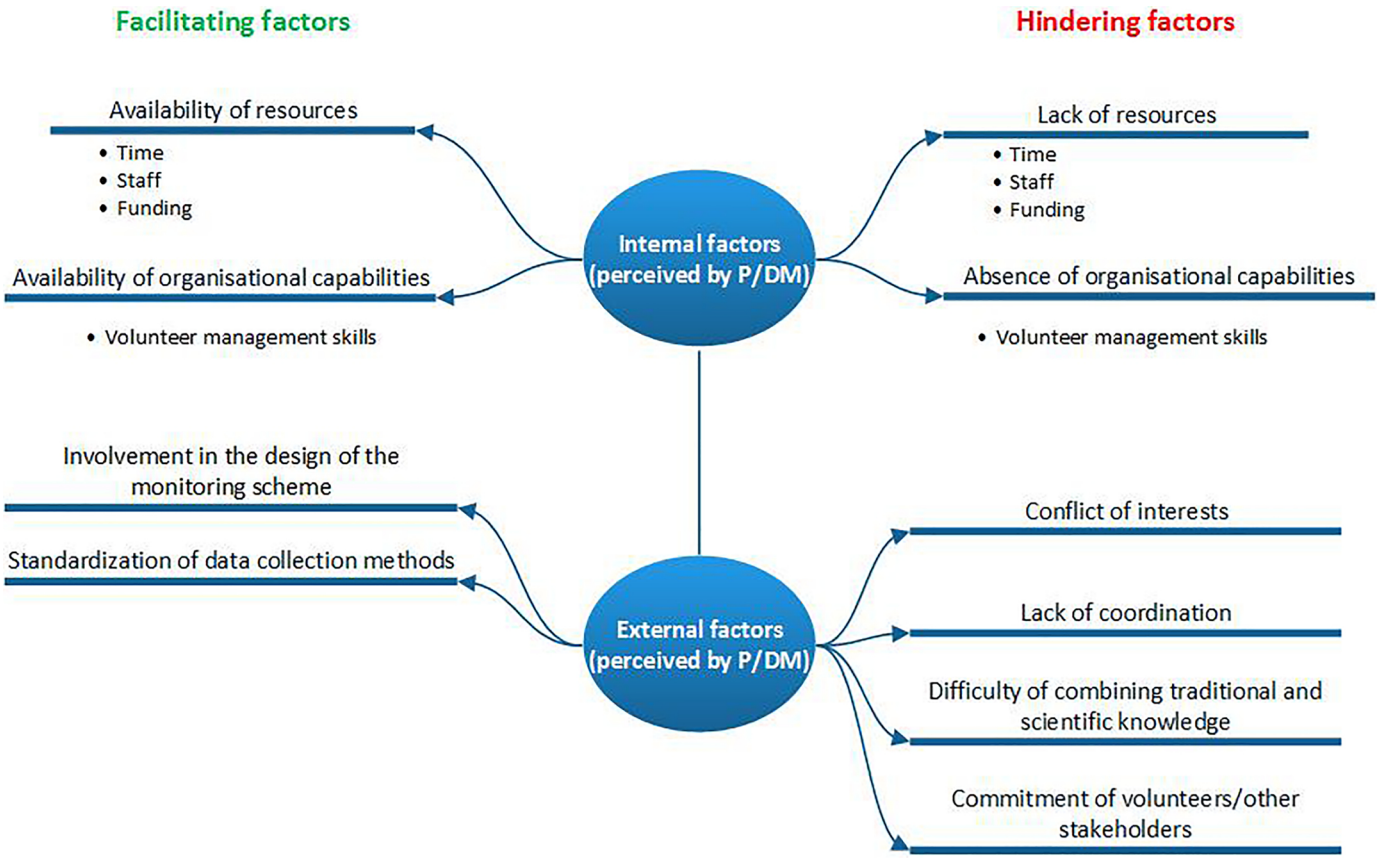

Fig. 13. Overview control beliefs of policy/decision makers re. CBM participation.

4.4.3. Control beliefs of policy/decision makers re. CBM participation

Control beliefs capture the perceived presence or absence of factors that can facilitate or inhibit an organization's activities pertinent to its participation in a CBM. Our findings for this category of beliefs are listed in Fig. 13 and are grouped into the domains explained in Section 3 (resources, organizational and technical capabilities, and circumstances).

The resource-related beliefs are the same as for scientists/data aggregators, with staff, time and/or funding availability or absence influencing the policy/decision makers' CBM participation. The same is true for the volunteer management skills.

Perceived facilitating circumstances are reported in the literature to consist of the policy/decision makers' involvement in the design of the monitoring scheme as well as the standardization of data collection methods. On the other hand, hindering circumstances were related to perceived conflicts of interest between stakeholders (e.g. priorities of authorities for monitoring and environmental management or other organisations' staff concerns regarding their own job security); lack of coordination between different monitoring activities (resulting in wasted resource); difficulties of combining traditional (indigenous) and scientific knowledge; and concerns about the commitment of volunteers/other stakeholders in the CBM.

5. Discussion

In the discussion of our findings from the critical analysis and integration of the literature, we focus on three aspects, namely the state of research into motivations for CBM, complementary and conflicting incentives for the respective key stakeholders in a CBM and their implications for the implementation of the SEIS pillars, and gaps to be addressed in future research on participation in CBM.

5.1. State of research into stakeholder motivations to participate in a CBM

The field of research into the behavioural aspects of CBM has expanded considerably during the last three years, with 70% of the papers included in our review published during that time. However, the quality of this field of research is compromised not only because of its very recent emergence but because of the mixed scientific quality of these studies, with few of them relying on sound theoretical frameworks and even fewer reporting about their methods in detail.

Moreover, most of the reviewed studies by far have focused on citizens as opposed to the other two key stakeholders. They have also converged in their focus on expected outcomes of participation and facilitating/hindering factors. The application of the TPB in this paper to organize and integrate the findings of the literature thus far for all key CBM stakeholders includes the concept of social pressure as a key element to influence behaviour.

Social pressure by key referents and/or via moral norms can in principle be a salient driver or obstacle for behaviour, incl. for CBM participation but most analysed studies had not yet conceived of this concept in the framing of their studies. A potentially salient driver for stakeholder participation in a CBM is therefore not included in many existing empirical studies and hence also absent from resulting guidance for CBM practitioners.

5.2. Complementary and conflicting incentives for the respective CBM actors

Overall, our results show that there are many drivers for stakeholder participation in CBMs (expected positive outcomes, supportive social pressure, facilitating factors and opportunities) but, at the same time, the identified range of barriers hindering participation is also considerable (expected negative outcomes, disapproving social pressure,

and hindering factors and missing opportunities). Moreover, it is important to bear in mind that the stakeholder types themselves are not homogenous groups – rather, they may differ (greatly) in terms of the incentives and barriers they perceive. The elicited beliefs highlight that, in principle, all key stakeholders may hold positive behavioural beliefs of desired outcomes as well as concerns about the implications of their CBM participation for themselves (as well as the organisations they work for) and even for society at large. These behavioural beliefs often have corresponding control beliefs, i.e. regarding the conditions and circumstances under which they can and will participate in a CBM, thus ensuring greater likelihood of achieving their desired outcomes. For example, citizen perceptions regarding the representation of community interests in decision making corresponds to beliefs about their involvement beyond data collection and instructions, training and professional support for their participation. Similarly, scientists/data aggregators hold beliefs about being able to generate enhanced evidence feeding into their organization's activities. These may correspond to awareness of the need to manage and train volunteers, reach the masses via media communication and ensure standard data collection methods are applied. The implications of these (potentially) corresponding beliefs are that the factors reported as control beliefs are often the key to ensuring that the expected outcomes (behavioural beliefs) can be realized, i.e. these issues (feedback, instructions, etc.) have to be carefully addressed via targeted efforts so that a virtuous cycle of past positive experience (CBM participation) can feed into continued involvement.

At the same time, potential clashes in the incentive systems of the respective stakeholders are also evident. For example, the identified citizen beliefs suggest that their participation can be more meaningful if they are involved at a more strategic level (e.g. having a say in what to monitor, where to monitor); the identified beliefs of scientists, on the other hand, indicate their preference to limit the participation of citizens to tasks led by scientists, e.g. in order to ensure the scientific rigor of the data collection. In addition, this dynamic is rendered more difficult by the concerns of policy/decision makers regarding their own priorities for monitoring and environmental management, concerns about coordination and difficulties of combining traditional and scientific knowledge.

In general terms, the outcomes of citizen participation in a CBM can be summarised as knowledge generation, learning and civic participation (Turreira-García et al., 2018). While all three outcomes are reflected in the elicited beliefs here across the key stakeholders, nevertheless, the respective expected outcomes in relation to decision making processes are noteworthy. The identified citizens' beliefs refer to mere representation of community interests in decision making (rather than higher levels of participation). The identified scientists' beliefs suggest that scientists may see a role for themselves in supporting the role of citizens in environmental management and governance, while the beliefs of policy/decision makers indicate that they envisage various roles for citizens (greater awareness, empowered communities and even enhanced stewardship of the community).

SEIS implementation is driven via its three pillars (content, infrastructure and governance). The SEIS content pillar refers to the types of content (data) required and their sources. Our results relate to the potential shift in role in terms of who decides what data is required in a given context and how it can be obtained, entering citizens as a key stakeholder in this part of the process. The range of beliefs identified indicates that this new role is not necessarily perceived positively nor granted automatically by policy/decision makers; neither is it inevitably appreciated or demanded by citizens (c.f. Wehn et al., 2018).

The SEIS infrastructure pillar concerns effective, web-enabled technical infrastructure. Our results indicate that in order for CBM to constitute a complementary component to national SEIS efforts, the sustained motivation of citizens to participate may depend on technological aspects such as reliable internet connections, availability of monitoring equipment, standardised monitoring protocols and suitable interfaces. This focus on the technical infrastructure needs to be complemented by efforts such as instructions, training, and feedback on the quality of citizen-based monitoring, as well as considerations regarding the in-situ conditions in the field. For scientists, the use of standardised monitoring protocols and the existence of quality assurance and control processes can be key motivational factors.

The SEIS governance pillar consists of "…*the cooperation and governance structures required to manage human resources, inputs and networking in relation to environmental information and data collection as well as its use in policy- making*" (Aggestam, 2019, p. 125). Our results indicate that these aspects influence the motivation to participate of all three key CBM stakeholders (citizens, scientists/data aggregators, and policy/decision makers), albeit in different forms. For citizens, this relates to the existence of a data and privacy policy, involvement beyond data collection (in other steps of the scientific method), feeding back their processed results and clarity on the use and/or impact of their contribution. For scientists/data aggregators, this may depend on partnerships and common interests among the involved stakeholders, communication with volunteers, and their own leading role in the process. The participation of policy/decision makers may depend on their involvement in the design of the monitoring scheme and may be rendered difficult by anticipated conflicts of interest, lack of cooperation, perceived dependence on volunteer commitment and difficulties with combining traditional and scientific knowledge, i.e. what counts as evidence in decision making and how (Adams and Sandbrook, 2013; Sandbrook and Adams, 2013).

Therefore, in any specific CBM, the careful alignment of the expectations, conditional factors and sources of social pressure across stakeholders is required. Moreover, it requires a careful process of reaching a shared understanding of the role of the CBM – and its stakeholders – in decision making, community-based management and scientific endeavours (e.g. Wehn et al., 2016; Vann-Sander et al., 2016). This will require explicit efforts to apprehend the respective stakeholders' incentive systems and variations in motivation, even within the key stakeholder groups (e.g. not all citizens are driven by the same beliefs or envisage the same level of involvement in a CBM). Such efforts can depart from the landscape of relevant beliefs mapped out here, coupled with tailored considerations of key referents (i.e. potential sources of social pressure) in a given local context.

5.3. Gaps to be addressed in future research on stakeholder motivations to participate in CBM

In general, the lack of sound, consistent conceptualization within and across studies in the field of research into stakeholder motivations to participate in a CBM suggests that there would be merit in pursuing future research that builds on relevant theoretical frameworks from the behavioural sciences and documents these research efforts in line with sound scientific principles, so that comparative analyses across different studies can advance the field.

Although our approach has served to organize the existing literature in a systematic fashion, this effort is inevitably influenced by the nature and quality of the consulted studies whose research design may have prevented eliciting specific types of beliefs for one or more of the key stakeholders of a CBM. Notably, since most other studies had not included the concept of social pressure in the framing of their studies, few findings have been generated in this respect for us to include in our integration of salient beliefs. Future research into stakeholder motivations can provide further insights into distinct sources of social pressure for the key CBM actors.

This literature review highlighted that, thus far, the motivations of the scientists/data aggregators and policy/decision makers, have not been studied as extensively as those of citizens. Far fewer studies – and therefore beliefs - could be identified for these stakeholders than for citizens.

Our study has shown that the belief systems of the key stakeholders

differ and therefore warrant separate attention, especially in view of the ultimate goal of informing CBM practice and stakeholder engagement based on stakeholder-specific insights about their incentive systems. Moreover, in some settings, private sector/industry actors may constitute an additional key actor in a CBM (e.g. Beza et al., 2017; McKay and Johnson, 2017) whose incentives need to be taken into account.

The findings of our review are of a qualitative nature (i.e. indicative of the nature and range of incentives and barriers for participation in a given CBM). What is required to inform CBM practice, is to reveal the 'strongest' drivers among identified incentives and barriers for the different CBM stakeholders in a given context. The TPB allows for the generation of such quantitative insights. Future research can therefore build on the incentive models generated here per key stakeholder to undertake primary empirical research (using scaled questions that are administered via a questionnaire) to a sufficiently large sample of respondents in order to identify the key incentives and barriers for each CBM community member. CBM practitioners can then draw on the resulting stakeholder-specific incentive systems as insight for targeted and tailored engagement strategies. As the results in this paper have already indicated, there is likely much impetus for planning CBM interventions with the involvement of all relevant stakeholders from the start.

Several calls have been made to consider the evolution of citizen motivations to participate in a CBM over time (e.g. Martin et al., 2016b; Lucrezi et al., 2018). We suggest that future research should examine the evolution of motivations of *all* key stakeholders, in order to inform and update stakeholder engagement strategies.

The TPB – although very comprehensive, and widely tested and validated – by itself does not serve to understand stakeholder interactions and dynamics. Building on the insights generated here and using complementary approaches, such as Agent Based Modelling, can help to model and explain stakeholder dynamics at play in particular settings.

6. Conclusions

This paper has presented a critical analysis and integration of the literature on incentives and barriers for participation in a CBM that pertain to the three core stakeholders of a CBM, namely citizens, scientists/data aggregators and decision/policy makers. Using the TPB an organizing framework has served to integrate the insights from diverse empirical studies on the motivations and challenges for CBM participation to identify complementary and conflicting incentives for the respective CBM actors.

Our results show that there are many drivers for stakeholder participation in CBMs (expectations about positive outcomes, supportive social pressure, facilitating factors and opportunities), but that the range of barriers potentially hindering participation is also considerable, stemming from expected negative outcomes, disapproving social pressure, and hindering factors and missing opportunities. In terms of theoretical contribution, our study has resulted in a systematic set of beliefs (and domains) that are tailored to the investigation into incentives and barriers for the participation of key stakeholders in a CBM. Based on the synthesis of insights generated here, future research can help to model and explain stakeholder dynamics at play in particular settings.

CBMs apply the SEIS concept of data and information generation, exchange and use at the local level and, as such, they constitute complementary (often bottom-up) initiatives to national SEIS efforts. Specifically, one of the initially conceived benefits of SEIS concerns 'citizen empowerment', defined as access to public information (European Commission, 2013). With their strong focus on the participation of citizens and the public in the *generation*, and not just access and use, of environmental data and information, CBMs are, in principle, an enhancement of this initial conceptualisation. The results of this study indicate that the definition of empowerment outcomes, and how and to what extent they can be obtained depends on the constellation of key stakeholders (citizens, scientists/data aggregators, and policy/decision makers) and, more specifically, on the extent to which their collective expectations, efforts, perceived pressures, capacities and opportunities in a given context are complementary, compatible and 'adding up'.

The insights presented in this paper resonate with those generated for SEIS at national level where the sharing and harmonisation of data has been found to be affected by (lack of) institutional support (i.e. social pressure) and human resources and infrastructure (i.e. control factors) and where evidence-informed policy making may be compromised by selective, subjective and biased use of environmental information. The latter is related to broader, ongoing debates about the role of evidence in decision making (e.g. Adams and Sandbrook, 2013; Haddaway and Pullin, 2013; Sandbrook and Adams, 2013) for which SEIS are not a panacea. Nevertheless, CBMs – if implemented in demand-driven ways that are sensitive to the incentive systems of its key stakeholders - may serve as a complementary, balancing mechanism, strengthening the involvement of diverse actors to help ground truth actual conditions and to demand greater accountability and transparency in related decision making processes. This paper has mapped the many interacting, perception-based factors that influence the extent to which CBMs can trigger a paradigm shift in environmental management.

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